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(54) **RETARDING SYSTEM FOR AN ELECTRIC DRIVE MACHINE**

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B60W 10/196	(2012.01)
B60W 10/188	(2012.01)
B60T 7/04	(2006.01)

(52) **U.S. Cl.**

CPC ***B60W 10/08*** (2013.01); ***B60T 7/042*** (2013.01); ***B60W 10/188*** (2013.01); ***B60W 10/196*** (2013.01); ***B60W 30/18109*** (2013.01); *Y10T 74/20528* (2015.01)

(58) **Field of Classification Search**

USPC ...... 188/2 A, 112 A, 162; 303/2, 13, 15, 152; 180/54.1, 65.25, 65.31; 74/512; 701/48

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,002,373	A	1/1977	Mori	
4,553,650	A	11/1985	Warwick et al.	
6,202,018	B1 *	3/2001	Stumpe et al.	701/70
6,431,661	B1	8/2002	Meyer	
6,591,711	B2	7/2003	Porter et al.	
6,910,747	B2	6/2005	Tsunehara	
7,439,695	B2	10/2008	Ngo et al.	
8,893,845	B2 *	11/2014	Stilwell et al.	180/370
2005/0269871	A1 *	12/2005	Saito	303/20
2006/0071545	A1 *	4/2006	Young et al.	303/115.1
2008/0306667	A1 *	12/2008	Karnjate et al.	701/70
2008/0309155	A1 *	12/2008	Audrezet et al.	303/15
2009/0240412	A1 *	9/2009	Cahill	701/70
2010/0025167	A1 *	2/2010	Staub et al.	188/156
2013/0233118	A1 *	9/2013	Khan et al.	74/514

FOREIGN PATENT DOCUMENTS

EP	1963156	9/2008
JP	2007106270	4/2007

* cited by examiner

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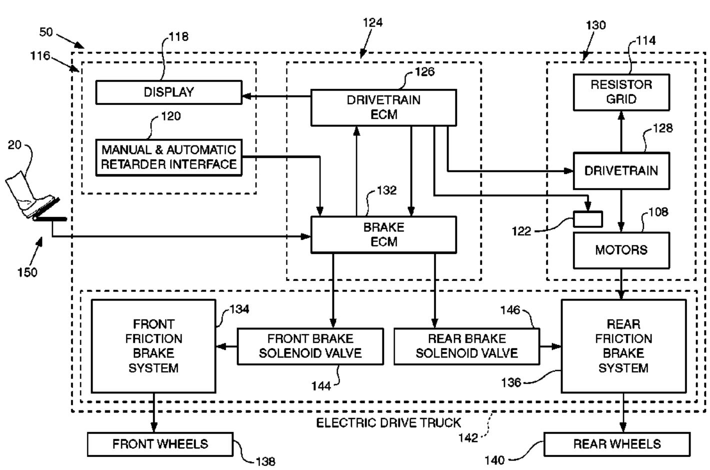
(57) **ABSTRACT**

A retarding system for an electric drive machine is provided. The retarding system includes an electrical retarding system and a hydraulic braking system. A single pedal controls both the electrical retarding system and the hydraulic braking system. The pedal includes a first range of travel that provides input to the electrical retarding system and a second range of travel that additionally controls the hydraulic braking system. The pedal further includes different levels of travel resistance in each of the two ranges of travel that correspond to providing inputs to the electrical retarding system and the hydraulic braking system.

5 Claims, 6 Drawing Sheets



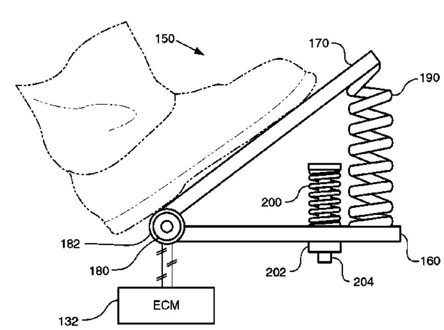
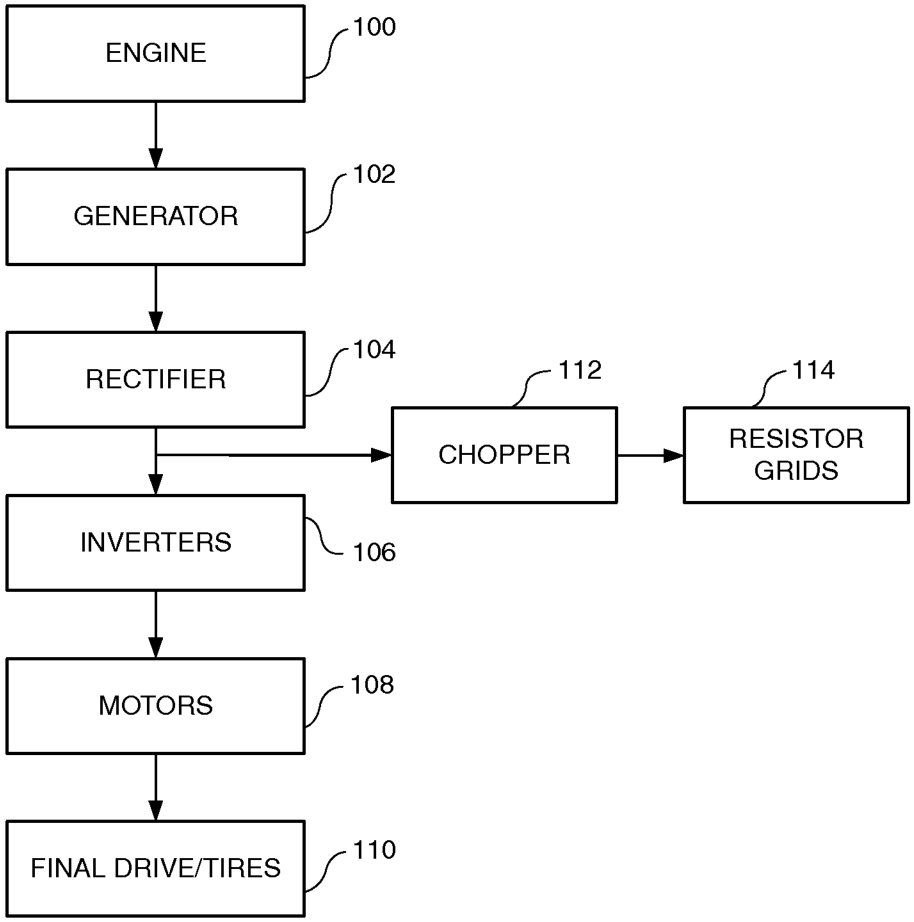


FIG. 1


ENGINE
100
GENERATOR
102
RECTIFIER
104
CHOPPER
112
RESISTOR GRIDS
114
INVERTERS
106
MOTORS
108
FINAL DRIVE/TIRES
110

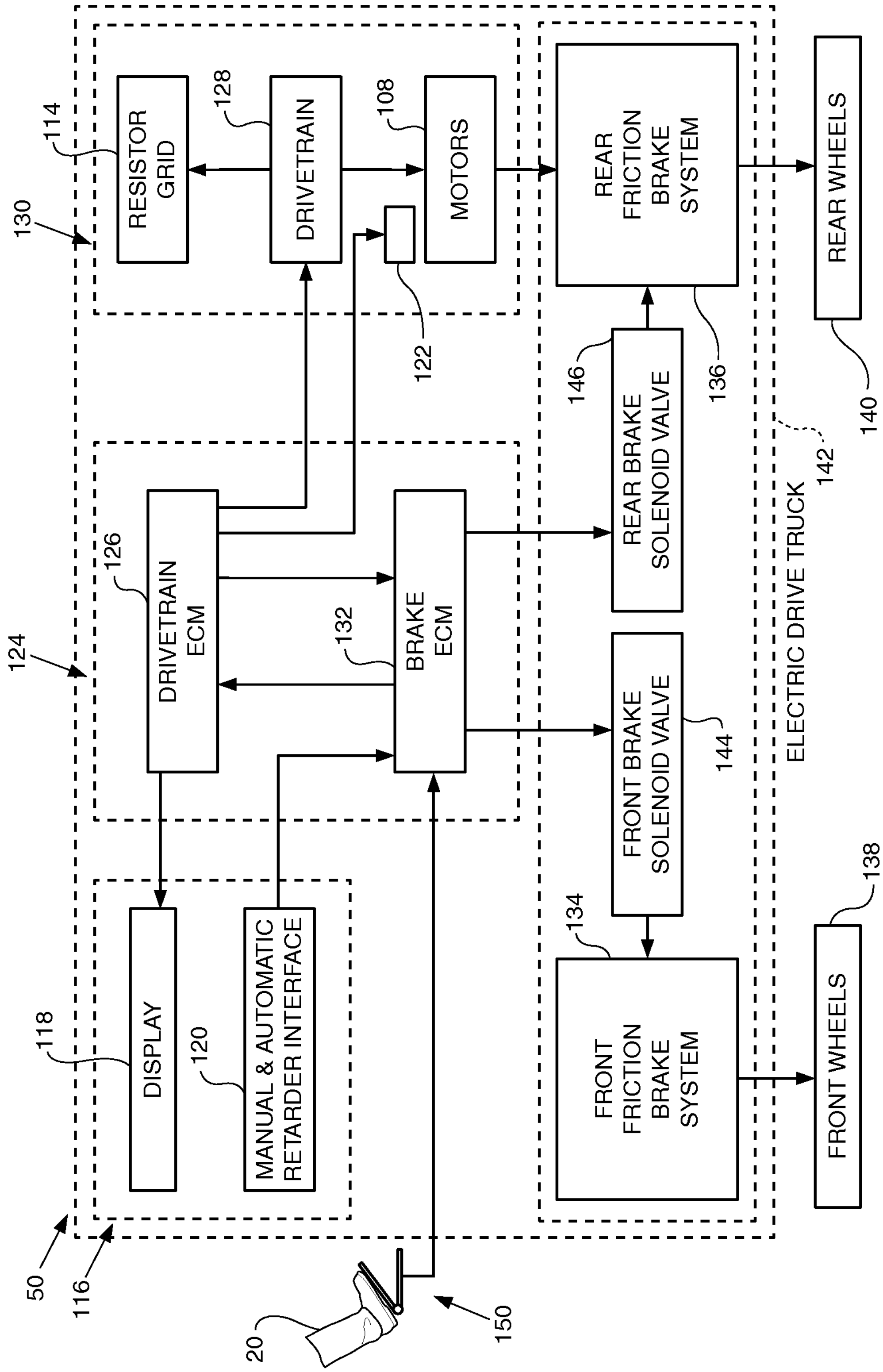

RESISTOR GRID
DRIVETRAIN
MOTORS
REAR FRICTION BRAKE SYSTEM
REAR WHEELS
DRIVETRAIN ECM
BRAKE ECM
REAR BRAKE SOLENOID VALVE
FRONT BRAKE SOLENOID VALVE
DISPLAY
MANUAL & AUTOMATIC RETARDER INTERFACE
FRONT FRICTION BRAKE SYSTEM
FRONT WHEELS
ELECTRIC DRIVE TRUCK
114
128
108
130
122
146
136
140
142
124
126
132
144
138
134
118
120
50
116
20
150

FIG. 2

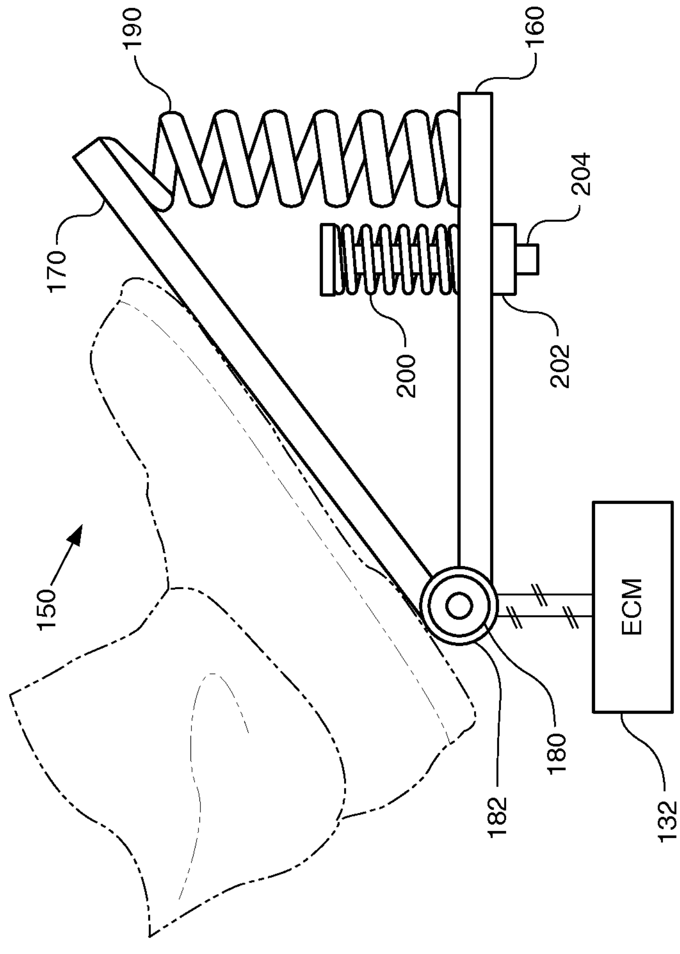


FIG. 3

FIG. 4

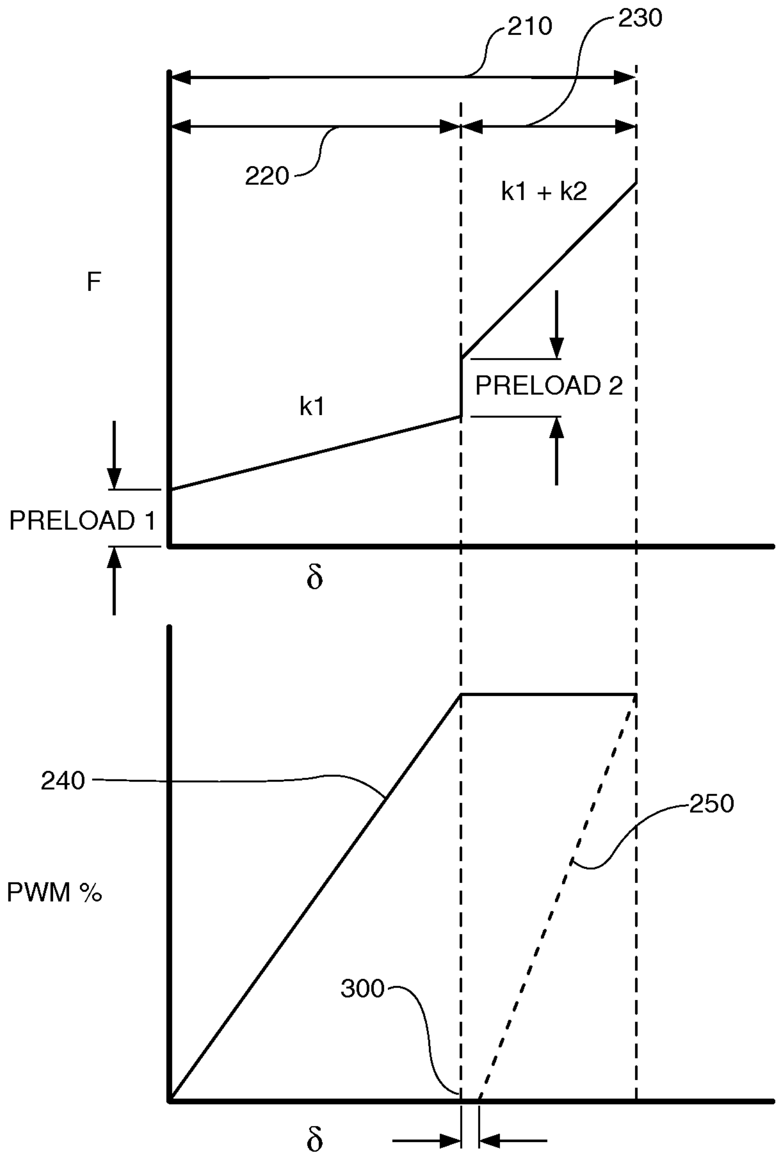


FIG. 5

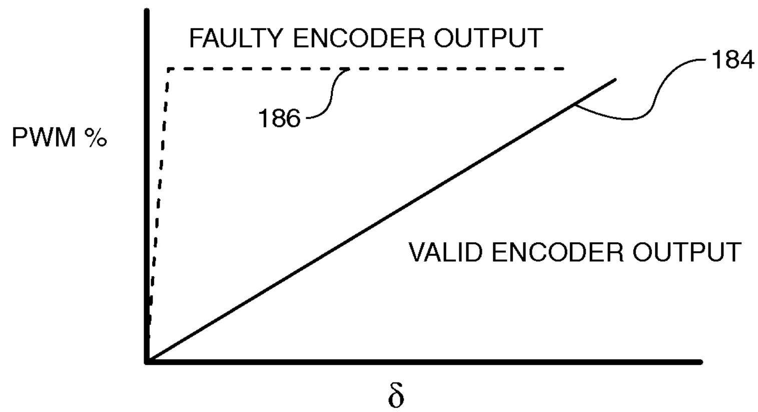


FIG. 6

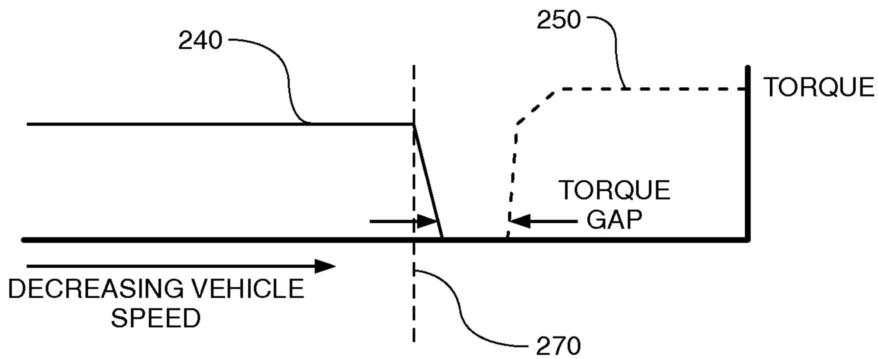


FIG. 7

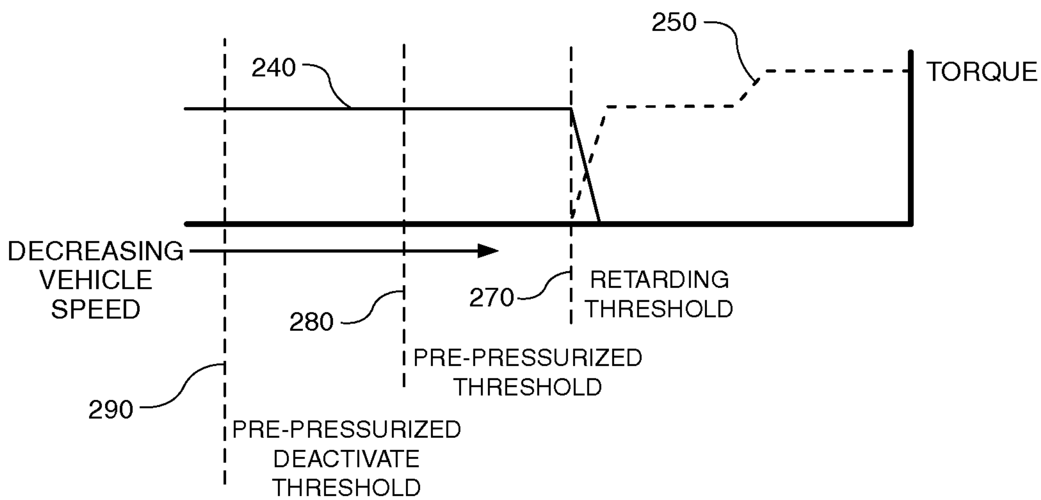
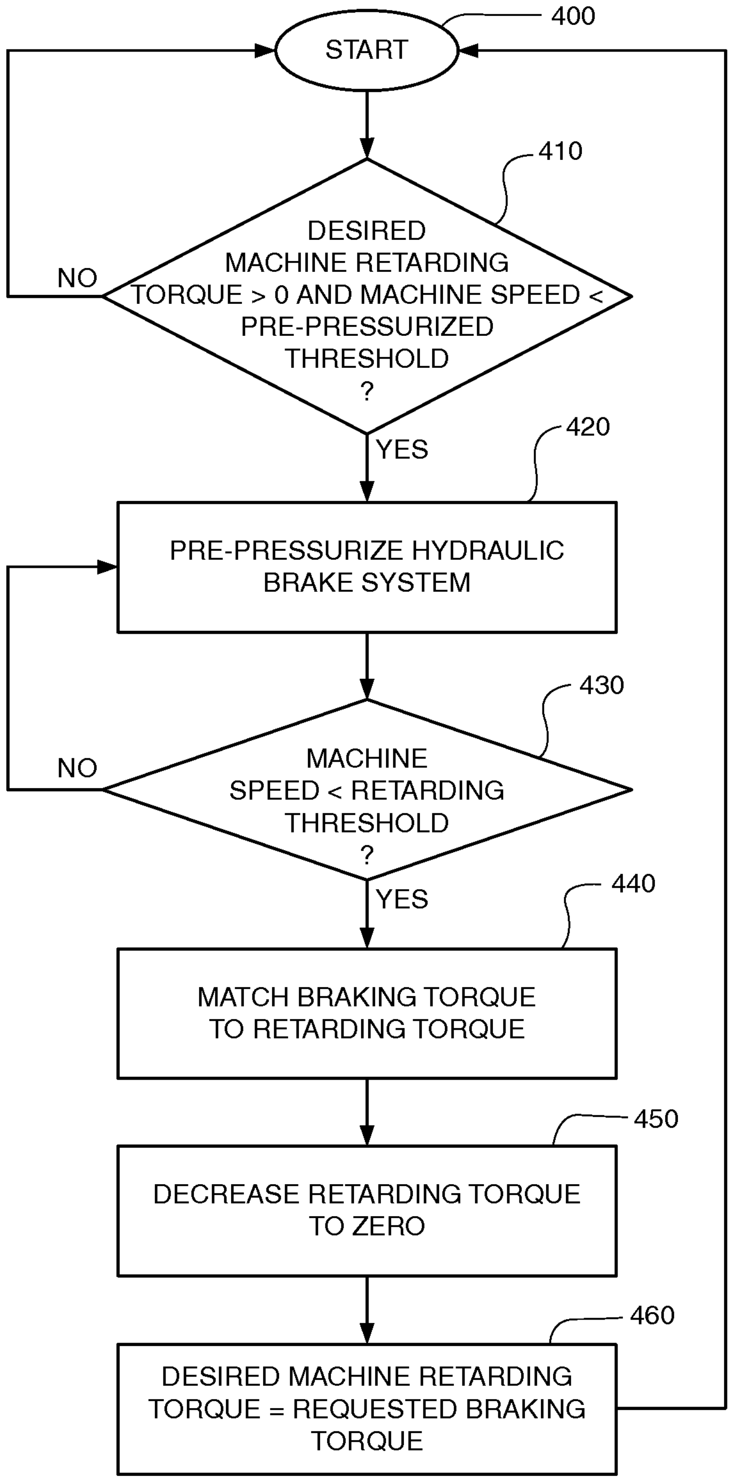


FIG. 8


400
START
410
DESIRED
MACHINE RETARDING
TORQUE > 0 AND MACHINE SPEED <
PRE-PRESSURIZED
THRESHOLD
?
NO
YES
420
PRE-PRESSURIZE HYDRAULIC
BRAKE SYSTEM
430
MACHINE
SPEED < RETARDING
THRESHOLD
?
NO
YES
440
MATCH BRAKING TORQUE
TO RETARDING TORQUE
450
DECREASE RETARDING TORQUE
TO ZERO
460
DESIRED MACHINE RETARDING
TORQUE = REQUESTED BRAKING
TORQUE

RETARDING SYSTEM FOR AN ELECTRIC DRIVE MACHINE

TECHNICAL FIELD

This disclosure relates generally to braking systems, and, more particularly to braking systems and methods that combine electric retarding and friction braking to slow a machine.

BACKGROUND

Braking systems are used in a large variety of machines and vehicles to control, slow and stop the machine. Exemplary machines include passenger vehicles, trains, dump trucks, and mining vehicles. Machines increasingly use electric drive systems to provide propulsion for the machine. For example, passenger vehicles may use a hybrid drive system whereby a traditional gasoline powered engine and an electric motor are both used to provide propulsion for the vehicle. Machines, such as a railway engines and off-road vehicles may use a diesel-powered engine to drive a generator, which provides electric power to a motor. The motor then provides propulsion for the machine.

Braking systems may take advantage of components in electric drive systems to provide braking for machines. For example, a hybrid passenger vehicle may include a regenerative braking system whereby the vehicle is slowed by the electric drive system while at the same time a battery in the vehicle is recharged. Railway engines use dynamic retarding to slow the train. Although brake systems utilizing electric drive systems have been used, these systems cannot stop a machine traveling at high speed quickly, nor can these systems consistently slow a heavily loaded machine traveling downhill or in slippery conditions.

Some prior systems include a manual retarder lever that enables the operator to control ground speed by manually selecting the level of retarding or automatic retarder control that automatically controls machine speed based the operator's machine speed setting. The manual or automatic retarder may control an electric retarding system. Additionally, the operator may control a traditional braking pedal to actuate hydraulic brakes. In this way, the operator can manually control both dynamic retarding and hydraulic brakes. However, this configuration may be difficult for an operator to control effectively. For example, if the speed setting lever is set to high, the operator may have to rely more on the service brakes. In a large, heavily loaded machine, this may lead to the service brakes overheating. In addition, excess service brake wear may occur on a machine if the service brakes are used for continuous retarding.

U.S. Pat. No. 20090,179,486 to Ikeda et al., issued Jul. 16, 2009, entitled "BRAKE SYSTEM IN ELECTRIC DRIVE DUMP TRUCK," discloses a brake system in an electric drive dump truck having a hydraulic brake and a generator-type retarder operated by a brake pedal. However, the Ikeda reference does not disclose how to provide feedback to the truck's operator when the brake system transitions between hydraulic function and retarder function. Nor does the Ikeda reference discuss how the brake system manages the transition between hydraulic braking and retarder operation when the retarder is not available.

SUMMARY OF THE INVENTION

In one aspect of the current disclosure, a retarding system for a machine having an electric drive system powering a set of rear wheels is disclosed. The retarding system comprises

an electrical retarding system associated with the electric drive system and configured to supply a retarding torque to the rear wheels in response to a requested retarding torque, a hydraulic brake system configured to supply a braking torque to a set of wheels in response to a requested braking torque, a brake pedal having a total range of travel comprising a first range of travel and a second range of travel, and an encoder configured to provide an output to the retarding system proportional to the total range of travel. The first range of travel is associated with a first level of travel resistance and is configured to provide a requested retarding torque in response to the output and the second range of travel is associated with a second level of travel resistance and is configured to provide a requested braking torque and a requested retarding torque in response to the output.

In another aspect of the current disclosure, a method for retarding a machine having an electric drive system powering a set of rear wheels, an electrical retarding system associated with the electric drive system and configured to supply a retarding torque to the rear wheels in response to a requested retarding torque, a hydraulic brake system configured to supply a braking torque to a set of wheels, is disclosed. The method comprises receiving an output from a brake pedal having a total range of travel comprising a first range of travel and a second range of travel, supplying a retarding torque in response to an output corresponding to the first range of travel that is associated with a first level of travel resistance and supplying a braking torque and a requested retarding torque in response to an output corresponding to the second range of travel that is associated with a second level of travel resistance.

In another aspect of the current disclosure, a pedal for providing inputs to two different machine retarding systems is disclosed. The pedal comprises a base, a pedal portion pivotally attached to the base and having a total range of travel, an encoder configured to provide an electrical signal corresponding to an angle between the base and the pedal portion, a first spring operably connected between the base and the pedal portion and having a first spring constant, and a second spring operably connected between the base and the pedal during a portion of the total range of travel and having a second spring constant.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a diagrammatic view of an electric drive system for use with the current disclosure;

FIG. **2** is a diagrammatic view of a retarding system for use with the current disclosure;

FIG. **3** is a diagrammatic view of a retarding pedal for use with the current disclosure;

FIG. **4** is a plot illustrating the function of the retarding system according to the current disclosure;

FIG. **5** is a plot illustrating a faulty encoder output according to the current disclosure;

FIG. **6** is a plot illustrating a torque gap according to the current disclosure;

FIG. **7** is a plot illustrating blended braking torque according to the current disclosure; and

FIG. **8** is a flow chart depicting a process for implementing blended braking torque according to the current disclosure.

DETAILED DESCRIPTION

Referring to the drawings, FIG. **1** illustrates a schematic view of an exemplary electric drive system including an electric retarding system for a machine. The exemplary electric drive system includes an engine **100**. Suitable engines include gasoline powered and diesel powered internal combustion engines. When in a drive configuration, the engine **100** powers a generator **102**. The generator **102** produces three-phase alternating current. The three-phase alternating current passes through a rectifier **104**, which converts the alternating current to direct current. An inverter or inverters **106** convert the direct current to variable frequency back to alternating current which feeds a motor **108**. By controlling the frequency of the current produced by the inverters **106**, the speed of the motor **108** is controlled. The motor **108** produces torque which powers the drive wheels **110**.

In an alternative example of the current disclosure, an engine is not needed and the motor **108** is driven directly from an electric power source, such as a battery. In some example of the current disclosures, one motor powers all drive wheels. In alternative example of the current disclosure, various numbers of motors are used to power drive wheels. For example, each drive wheel may have an individual motor associated with the wheel.

When operating in an electric braking, also known as electric retarding, configuration, the drive wheels **110** power the motor **108**. Driving the motor **108** places a torque on the drive wheels **110** and causes them to slow, thus braking the machine. The motors **108** generate alternating current. The inverters **106** convert the alternating current to direct current and feed the current to a chopper **112**, which acts as a direct current to direct current converter, and resistor grid **114**. The power generated by the motors **108** is thus dissipated thru heat by the resistor grid **114**. However, in an alternative example of the current disclosure, the power generated by the motors **108** is stored for later use. In one example of the current disclosure, the power generated by the motors **108** is stored in an electric battery. The energy in the electric battery can then be used in drive mode to power the motors **108** and propel the machine.

The braking system operates in two modes. In first mode, the electric retarding system **130** supplies retarding torque **240**. In a second mode, the electric retarding system supplies maximum retarding torque **240**, while the hydraulic brake system **142** provides braking torque **250**.

Turning to FIG. **2**, a block diagram illustrating a braking system for a machine including a hydraulic brake system **142** and an electric retarding system **130** is illustrated. In one example of the current disclosures, a user interface **116** allows the operator of the machine to view status information relating to the braking system on a display **118**. Displayed information may include whether the electric retarding capacity has been exceeded. Additionally, status information regarding whether a front brake enable selection is set, automatic retarding settings and manual retarding settings may be shown on the display **118**.

A speed sensor **122** is operably connected to receive information regarding the ground speed of the machine **10**. The speed sensor **122** may be connected to a motor **180**, front wheels **138**, or rear wheels **140**. The speed sensor **122** maybe connected to either drivetrain ECM **126** or the brake ECM **132**.

The user interface **116** includes a manual and automatic retarder interface **120**. The user interface **116** interacts with a controller **124**. The controller **124** may include one or more control modules. In the illustrated example of the current disclosure, two electronic control modules (ECM) are used to implement the controller **124**. The drivetrain ECM **126** controls elements in the drivetrain **128**. The drivetrain **128** includes the engine **100**, generator **102**, rectifier **104**, inverters **106**, motor **108**, and chopper **112**. When braking the machine, the electric retarding system **130** includes the rectifier **104**, inverters **106**, motor **108**, and chopper **112** and the resistor grid **114**. In electric retarding mode, the drivetrain ECM **126** commands the electric retarding system **130** to provide a requested desired machine retarding torque and a ratio of retarding torque splits between sets of wheels. Thus, the drivetrain ECM **126** may command the machine to apply the proper ratio of torque splits between, for example a set of front wheels and a set of rear wheels.

In one example of the current disclosure, the drivetrain ECM **126** receives signals indicating the front brake retarding enable switch **122** status, the manual retarder torque setting and the auto retarder torque setting from a brake ECM **132**. Based on these signals, the drivetrain ECM **126** calculates the desired machine retarding torque to be applied to the machine. The drivetrain ECM **126** provides signals indicating the desired machine retarding torque and the requested electric retarding torque to the brake ECM **132**. The brake ECM, based on these signals, determines whether the requested electric retarding torque is sufficient to provide the full desired machine retarding torque. If additional braking is necessary to meet the desired machine retarding torque, the brake ECM requests a ratio of additional braking torque from the front friction brake system **134** and the rear friction brake system **136**. The front friction brake system **134** connects to a front set of wheels **138** and the rear friction brake system **136** connects to a set of rear wheels **140**. In one example of the current disclosure the front friction brake system **134** and the rear friction brake system **136** are part of a hydraulic brake system **142**. In one example of the current disclosure, the hydraulic brake system includes a front brake solenoid valve **144** for controlling the flow of hydraulic fluid to the front friction brake system **134**. Likewise, a rear brake solenoid valve **146** controls the pressure of hydraulic fluid to the rear friction brake system **136**. The front friction brake system **134** and rear friction brake system **136** each include a hydraulic brake piston **148** that applies hydraulic force to actuate said brakes.

In another example of the current disclosure, a single brake solenoid valve may control both the front and rear friction brake systems **134**, **136**. In yet another example of the current disclosure, only the rear brake solenoid valve **146** may be present.

Turning to FIG. **3**, a brake pedal **150** includes a pedal portion **170** pivotally attached to a base **160**. The pedal portion **170** is designed to pivot when depressed by an operator's foot. The degree of depression is measured by an encoder **180**. The encoder **180** is configured to indicate angular position by sending an electrical signal to an ECM, such as a brake ECM **132**. The brake ECM **132** measures the electrical signal, and compares it to certain parameters to determine its validity, then to other parameters to calculate the measured angular position. The encoder **180** may be of the optical type. Various such encoders **180** are known in the art. The output of the encoder **180** may be a pulse-width modulated (PWM) signal as is known in the art. The output may be expressed as a percentage of the duty cycle of the output signal, from 0 to 100%. In one alternative of the current disclosure, a second encoder **182** may be included for redundancy. The second encoder **182** may identical to the first encoder **180**. The second encoder **182** is also electrically connected to an ECM, such as a brake ECM **132**.

The pedal portion **170** has a total travel range **210** as it pivots on base **160**. The total travel range **210** is divided into a first travel range **220** and the second travel range **230**. Pivoting between the pedal portion **170** and the base **160** is resisted by force from a first spring **190** when pivoting within the first travel range **220**, and an additional second spring **200** when pivoting within the second travel range **230**. The first spring **190** is operably located between the pedal portion **170** and the base **160**. The change in force provided by the first spring **190** is characterized by its spring constant k**1** and follows Hooke's law $\Delta F1=k1*\Delta x$, where Δx is the change in distance between base **160** and pedal portion **170** as it pivots. The change in force provided by the second spring **200** is likewise characterized by $\Delta F2=k2*\Delta x$. Therefore, the change in resisting force when the pedal portion **170** is pivoting within the second travel range **230** is given by $\Delta F1+\Delta F2$.

Turning to FIG. **4**, it is seen that a preload may be applied to either first spring **190** or second spring **200**. The preload may be achieved by using a device that provides a degree of compression of the springs **190**, **200** before they are compressed by pivoting. For instance, the length of the first spring **190** could be greater than the distance between the pedal portion **170** and the base **160**. The pivot angle between the pedal portion **170** and the base **160** may be limited in order to achieve a preload. Preload on second spring **200** could be achieved by employing a mechanical stop **202** on the second spring **200**. The stop **202** is configured to stop movement of a plunger **204** thereby providing a preload on second spring **200**.

INDUSTRIAL APPLICABILITY

The brake pedal **150** is designed to indicate to an operator **20** of a machine **10** when the retarding system **50** is transitioning between a mode providing retarding torque **240**, and a mode providing braking torque **250**. The brake pedal **150** provides a greater travel resistance during the second travel range **230** than in the first travel range. The higher travel resistance is great enough to be noticed by the operator **20**. The higher travel resistance is provided by the addition of the spring rate of second spring **200**. FIG. **4** shows angular displacement, or pivoting, between the pedal portion **170** and the base **160** on the horizontal axis. The vertical axis on the top plot shows the force provided by the operator **20** to pivot the pedal portion **170**. The vertical axis on the bottom plot shows the encoder **180** output as a percentage. When the pedal portion **170** is pivoting in the first travel range **220**, the travel resistance follows the slope of k**1**. In the first travel range **220**, the retarding system **50** is commanded to provide a retarding torque **240**. When the pedal portion **170** is pivoting in the second travel range **230**, the travel resistance follows the slope of k**1**+k**2**. In the second travel range **230**, the retarding system **50** is commanded to provide a braking torque **250**. The difference between the two spring rates during the transition between the first travel range **220** and second travel range **230** is sufficient to be noticed by an operator **20** using the brake pedal **150**.

In one example of the current disclosure, the transition between the first travel range **220** and second travel range **230** may also include a preload that must be overcome before the pedal portion **170** will pivot in the second travel range **230**. Refer to FIG. **4**. The force needed to overcome the preload may be between 10 and 50% of the total force needed to pivot the pedal portion **170** through the second travel range **230**. The force needed to overcome the preload may provide an additional indication to the operator **20** that the pedal portion **170** is transitioning to the second travel range **230** and that the retarding system **50** is entering a mode to provide braking torque **250**. A preload of between 50 and 100 N may be used.

In another example of the current disclosure, the first travel range **220** may include a preload that must be overcome before the pedal portion **170** will pivot in the first travel range **220**. Refer to FIG. **4**. The force needed to overcome the preload may be between 10 and 50% of the total force needed to pivot the pedal portion **170** through the first travel range **220**.

In another example of the current disclosure, there may be provided a dead band region **300** at the beginning of the second travel range **230** in which no braking torque **250** is commanded. The dead band region **300** prevents the operator **20** from inadvertently commanding a braking torque **250** when the pedal portion **170** is at the transition between the first travel range **220** and second travel range **230**.

In one example of the current disclosure, the encoder **180** and second encoder **182** are both connected to an ECM, such as a brake ECM **132**. The second encoder **182** provides signal redundancy such that the brake ECM **132** always receives at least one valid signal indicating the sensed angle position between the pedal portion **170** and the base **160**. The brake ECM **132** may use both signals to indicate the sensed angle position. Alternatively, it may use the signal from encoder **180** under normal conditions. The brake ECM **132** may then switch to the signal from second encoder **182** if the signal from **180** is determined to be faulty. The fault can be determined as is known in the art. As shown in FIG. **5**, if a signal is determined to be faulty the brake ECM **132** will use the other, valid, signal to indicate the sensed angle position. Brake ECM **132** may send a fault signal to the drivetrain ECM **126** if a faulty encoder output is detected. The drivetrain ECM **126** may sound an audible alarm and/or display a fault message or icon on the display **118**. Similarly, if the signals from encoders **180** and **182** are not determined to be faulty, but rather disagree, then a number of actions may be taken. For instance, the brake ECM **132** may switch to the minimum signal or the maximum signal depending on the application.

In another aspect of the current disclosure, the brake ECM **132** is configured to use the hydraulic brake system **142** provide braking torque **250** throughout the total travel range **210** if a failure is detected in the electric retarding system **130**. For instance, if a failure such as a ground fault or open circuit is detected in the resistor grid **114**, motors **108**, or drivetrain **128** is detected, the drivetrain ECM **126** may send a fault signal to the brake ECM **132**. The brake ECM **132** can then use the hydraulic brake system **142** to provide braking torque **250** for any pedal position within the total travel range **210**. Upon detection of a failure in the electric retarding system **130**, the drivetrain ECM **126** may sound an audible alarm and/or display a fault message or icon on the display **118**.

At low speed, it can be difficult for the electric retarding system **130** to provide sufficient retarding torque **240** to slow or stop the machine **10**. FIG. **6** shows how retarding torque **240** drops to zero below a retarding threshold **270**. In previous systems, the retarding system **50** might then engage the hydraulic brake system **142** that would provide braking torque **250** in order to slow or stop the machine **10**. FIG. **6** shows a plot of vehicle speed on the horizontal axis (decreasing from left to right) and torque on the vertical axis. As shown in FIG. **6**, the previous systems would cause a torque gap between the retarding torque **240** and the braking torque **250**. The gap exists in part due to a time delay between when the hydraulic brake system **142** activates the front brake solenoid valve **144** and the rear brake solenoid valve **146**, to when enough pressure is built up in the hydraulic brake pistons **148** to provide braking torque **250**. The previous systems therefore produce at least two negative results. First, the torque gap allows the machine **10** to free-wheel for a period of time even though the brake pedal **150** has commanded retarding. Second, when the braking torque **250** becomes available it may be higher in magnitude than the retarding torque **240** at low speeds. The higher braking torque **250** leads to abrupt retarding of the machine **10**.

One aspect of the current disclosure provides for a solution to smoothly transition between retarding torque **240** and braking torque **250** at low speeds. The system defines a retarding threshold **270**, a pre-pressurize threshold **280**, and a pre-pressurize deactivation threshold **290**. The plot in FIG. **7** shows a plot of vehicle speed on the horizontal axis (decreasing from left to right) and torque on the vertical axis. When speed of the machine **10** drops below the pre-pressurize threshold **280**, the brake ECM **132** activates front brake solenoid valve **144** and rear brake solenoid valve **146** in order to pre-pressurize the hydraulic brake pistons **148** in the front and rear friction brake system **134**, **136**. When the speed of the machine **10** drops below the retarding threshold **270**, retarding torque **240** quickly drops to zero, while the braking torque **250** increases. There is little or no torque gap in this instance because the time delay to engage the hydraulic brake system **142** has been minimized by pre-pressurizing the front and rear friction brake systems **134**, **136**. If the speed of the machine **10** increases above a pre-pressurize deactivate threshold **290**, pressure in the hydraulic brake system **142** is returned to normal. The pre-pressurize deactivate threshold **290** may include hysteresis with respect to the speed of the machine **10** as is known in the art.

When the speed of the machine **10** drops below the retarding threshold **270**, the brake ECM **132** matches the braking torque **250** to the level previously provided by the retarding torque **240**. Therefore, the retarding system **50** may provide braking torque **250** when the brake pedal **150** is in the first travel range **220** in order to replace lost retarding torque **240** capability. The brake ECM **132** uses the commanded torque from the motors **108** multiplied by the final drive ratio connected to the rear wheels **140** in order to determine the desired machine retarding torque. The brake ECM **132** then calculates the pressure that the hydraulic brake system **142** needs to supply in order to match the retarding torque **240**. The pressure in the hydraulic pressure is related to braking torque **250** by an expression given by N*m/kPa*Final Drive Ratio. For example, the front friction brake system **134** may require about 35/200 N*m/kPa while the rear friction brake system **136** may require 35/200 N*m/kPa. The braking torque **250** is matched to the retarding torque **240** for a predetermined duration before command of the braking torque **250** is set equal to the desired machine retarding torque requested by brake pedal **150**.

The flow chart in FIG. **8** shows how a method of blending retarding torque **240** into braking torque **250** when the machine **10** is at low speed may be implemented. First, the method starts at box **400** and proceeds to decision box **410**. The method then checks to see if the desired machine retarding torque is greater than zero, i.e. the brake pedal **150** has been depressed by some degree. The method then checks to see if the speed of the machine **10** is below the pre-pressurize threshold **280**. If the answer to both is YES, then the method proceeds to action box **420**. Otherwise the method returns to the start box **400**. At action box **420**, the hydraulic brake system **142** pre-pressurizes the front friction brake system **134** and/or the rear friction brake system **136**. The method then proceeds to decision box **430**, where the method checks to see if the speed of machine **10** is less than the retarding threshold **270**. If the answer is YES, the method proceeds to action box **440**. If the answer is NO, the method returns to action box **420**. At action box **440**, the method sets the braking torque **250** equal to the retarding torque **240**. From action box **440**, the method proceeds to action box **450**, where retarding torque is decreased to zero. The method then proceeds to action box **460**, where braking torque **250** is set equal to the desired machine braking torque.

What is claimed is:

1. A retarding system for a machine having an electric drive system powering a set of rear wheels comprising:

an electrical retarding system associated with the electric drive system and configured to supply a retarding torque to the rear wheels in response to a requested retarding torque;

a hydraulic brake system configured to supply a braking torque to a set of wheels in response to a requested braking torque;

a brake pedal having a total range of travel comprising a first range of travel and a second range of travel;

an encoder configured to provide an output to the retarding system proportional to the total range of travel;

wherein the first range of travel is associated with a first level of travel resistance and is configured to provide a requested retarding torque in response to the output and the second range of travel is associated with a second level of travel resistance and is configured to provide a requested braking torque and a requested retarding torque in response to the output;

wherein the retarding system includes a sensor configured to detect a machine speed; and

sets the braking torque equal to the retarding torque if the machine speed drops below a retarding threshold.

2. A retarding system for a machine having an electric drive system powering a set of rear wheels comprising:

an electrical retarding system associated with the electric drive system and configured to supply a retarding torque to the rear wheels in response to a requested retarding torque;

a hydraulic brake system configured to supply a braking torque to a set of wheels in response to a requested braking torque;

a brake pedal having a total range of travel comprising a first range of travel and a second range of travel;

an encoder configured to provide an output to the retarding system proportional to the total range of travel;

wherein the first range of travel is associated with a first level of travel resistance and is configured to provide a requested retarding torque in response to the output and the second range of travel is associated with a second level of travel resistance and is configured to provide a requested braking torque and a requested retarding torque in response to the output;

wherein the hydro-mechanical brake system comprises a hydraulic brake piston; and

the hydraulic brake system pre-pressurizes the hydraulic brake piston with brake fluid if the machine speed drops below a pre-pressurize threshold which is higher than the retarding threshold.

3. A retarding system for a machine having an electric drive system powering a set of rear wheels comprising:

an electrical retarding system associated with the electric drive system and configured to supply a retarding torque to the rear wheels in response to a requested retarding torque;

a hydraulic brake system configured to supply a braking torque to a set of wheels in response to a requested braking torque;

a brake pedal having a total range of travel comprising a first range of travel and a second range of travel;

an encoder configured to provide an output to the retarding system proportional to the total range of travel;

wherein the first range of travel is associated with a first level of travel resistance and is configured to provide a requested retarding torque in response to the output and the second range of travel is associated with a second level of travel resistance and is configured to provide a requested braking torque and a requested retarding torque in response to the output;

wherein the brake pedal includes a second encoder configured to provide an output to the retarding system proportional to the total range of travel, wherein the retarding system, upon receiving either of the encoder outputs that is faulty, uses the other of the first or second encoder outputs to provide either of the requested braking torque or requested retarding torque.

4. A method for retarding a machine having an electric drive system powering a set of rear wheels, an electrical retarding system associated with the electric drive system and configured to supply a retarding torque to the rear wheels in response to a requested retarding torque, a hydraulic brake system configured to supply a braking torque to a set of wheels, comprising:

receiving an output from a brake pedal having a total range of travel comprising a first range of travel and a second range of travel;

supplying a retarding torque in response to an output corresponding to the first range of travel that is associated with a first level of travel resistance; and

supplying a braking torque and a requested retarding torque in response to an output corresponding to the second range of travel that is associated with a second level of travel resistance,

wherein the retarding system includes a sensor configured to detect a machine speed; and

setting the braking torque equal to the retarding torque if the machine speed drops below a retarding threshold;

wherein the hydraulic brake system comprises a hydraulic brake piston; and

pre-pressurizing the hydraulic brake piston with brake fluid from the hydraulic brake system if the machine speed drops below a pre-pressurize threshold which is higher than the retarding threshold.

5. A pedal for providing inputs to two different machine retarding systems comprising

a base;

a pedal portion pivotally attached to the base and having a total range of travel;

an encoder configured to provide an electrical signal corresponding to an angle between the base and the pedal portion;

a first spring operably connected between the base and the pedal portion and having a first spring constant; and

a second spring operably connected between the base and the pedal during a portion of the total range of travel and having a second spring constant, and

a second encoder configured to provide an electrical signal corresponding to the angle between the base and the pedal portion.

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